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ABSTRACT

A system of instruction for technical mathematics which utilizes programmed materials, continual diagnostic assessment, and tutoring is described. The system was developed at the Milwaukee Area Technical College. The first section of this paper states the philosophy of the project, lists the programmed texts used, enumerates special features of the project, and describes the use of the system of instruction. The second section analyzes the system of instruction, giving details on how the system works, characteristics of students enrolled in the courses, course content, student evaluation, teacher role, and typical results of the program. Section three discusses the use of the system in secondary schools, including development of a two-year technical mathematics sequence for grades 11 and 12. The final section looks into future directions for the program. (DT)

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A SYSTEM OF INSTRUCTION FOR CAREER MATHEMATICS

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ABSTRACT

This paper describes a highly-organized, highly-assessed, and highly-successful system of instruction for technical mathematics which has been developed at the Milwaukee Area Technical College. Published under the title, MATC Mathematics Series by the Addison-Wesley Publishing Company, the three major instructional components of this system are programmed materials, continual diagnostic assessment, and tutoring. The system was developed over a seven-year period, with the initial funding obtained from the Carnegie Corporation of New York.

Because the system takes into account the low entry skills of the students, some "articulation" and "content" problems have yet to be solved. As part of this solution, the Milwaukee Area Technical College is presently conducting National Science Foundation Institutes in Technical Mathematics for Secondary School Teachers in which the secondary schools in the Milwaukee area are being encouraged to include a two-year technical mathematics sequence in grades 11 and 12 in their curriculum. This two-year technical mathematics sequence is seen as a first step in the direction of a full four-year career mathematics track in secondary schools for students who do not intend to obtain a baccalaureate degree. The establishment of this full four-year career mathematics track will be necessary if the concept of career education is to have an impact on the secondary school curriculum.

This paper describes and discusses a system of instruction developed at the Milwaukee Area Technical College (MATC) for a two-semester technical mathematics course. The paper is divided into four sections:

1. An introduction or overview.
2. A description of the system of instruction.
3. The use of the system in secondary schools.
4. Discussion and future directions.

A more detailed description of the system is available in two sources: (1) Mathematics for the Majority, a research report available from the authors (1015 North Sixth Street, Milwaukee, Wisconsin 53203), and (2) The MATC Mathematics Series (especially the Teacher's Manual) available from the Addison-Wesley Publishing Company (Reading, Massachusetts 01867).

INTRODUCTION

In this introduction, the following points will be briefly discussed: (1) the history of the MATC Mathematics Project, (2) its staff, (3) its philosophy, (4) its product - the MATC Mathematics Series, (5) some special features of the system of instruction, (6) field testing, and (7) the use of the system of instruction.

History. The Milwaukee Area Technical College Mathematics Project has been in existence for seven years. Originally funded in 1965 by a $200,000 grant from the Carnegie Corporation of New York, it has been subsequently funded by the Milwaukee Area Technical College with partial support from the Wisconsin State Board of Vocational, Technical and Adult Education. The goal of the project has been to improve the instruction in a two-semester technical mathematics course taken each year by approximately 650 students in the Day and Evening Divisions at MATC. Improvement was needed in three respects:

1. A reconsideration of the content to make it totally relevant for basic science and technology.

2. A reduction in the dropout rate, which had been 40 percent in the first semester of the course.

3. An increase in the achievement level, which had been only 55 percent or 60 percent on predominantly basic-skill final examinations.

Staff. The staff members possess a unique combination of educational backgrounds, skills, and experience. Dr. Thomas J. McHale, the Project Director, is an experimental psychologist with a major interest in the psychology of learning. Mr. Paul T. Witzke is an instructor at MATC with 25 years experience teaching mathematics, science, and a variety of technical courses. Other staff members are mathematics instructors at MATC. This unique combination of personnel has contributed the following positive contributions to the efforts of the project:

1. An understanding of the entry skills and learning characteristics of the students.

2. A choice of content which is both relevant and realistic.

3. A knowledge of the learning process.

4. A knowledge of various assessment techniques.

5. A spirit of innovation and a willingness to change.

Philosophy. During the project, the staff has developed a philosophy of relevance, realism, and accountability which is outlined in the following statements:

1. The course content should include only those mathematical topics which are relevant for basic science and technology.

2. The course content should take into account both the entry skills and the learning characteristics of the students.

3. Because the content is relevant, the instructional goal should be a mastery level of achievement.

4. The success of the instruction should be highly assessed in order to assure that a mastery level of achievement is attained.

5. Since the students are not being trained to become formal mathematicians, the approach to mathematics should be intuitive and numerical, with a deemphasis on structure and proof.

MATC Mathematics Series. The product of the project is a system of instruction published under the title, MATC Mathematics Series, by the Addison-Wesley Publishing Company. The three major components of this system of instruction are programmed materials, continual diagnostic assessment, and a teacher. Each component is described briefly below:

1. Programmed Textbooks - The Series includes four programmed textbooks: BASIC ALGEBRA, CALCULATION AND SLIDE RULE, BASIC TRIGONOMETRY, and ADVANCED ALGEBRA. These textbooks include frequent short self-tests (with answers) which are an integral part of the instruction.

2. Diagnostic Assessment - Each textbook is accompanied by a test booklet which includes a diagnostic test for each assignment, chapter tests (three equivalent forms), and a comprehensive final examination. Entry diagnostic tests in arithmetic and algebra are provided. A complete set of keys is provided in each test booklet for all tests in that booklet.

3. A Teacher - A teacher is essential to the success of this system. Its success depends on the teacher's ability to diagnose learning difficulties and to remedy them by means of tutoring. Its success also depends on the teacher's skill in maintaining a suitable effort by each student. This new role for the teacher can be best described by

calling him a "manager of the learning process." Teachers who use the system correctly find that this new role is a highly professional and satisfying one because it permits them to deal successfully with the wide range of individual differences which exist in any group of students.

Special Features. Some of the major features of the system of instruction are listed below:

Individual Attention - The system is designed so that the teacher can deal with the learning problems of individual students.

Learnability - When the system is used correctly, teachers can expect (and will obtain) a high level of learning in a high percentage of students.

Relevant Content - All of the content has been chosen on the basis of its relevance for basic science and technology. The content also provides a basis for the study of more advanced topics in mathematics itself.

Assessment - The many tests which are provided enable the teacher to maintain a constant assessment of each student's progress and the overall success of the system.

Student Motivation - Because students receive individual attention and have a high probability of success, motivation problems are minimized and student attitudes are generally quite positive.

Flexibility - The system can be used either in a conventional classroom or in a learning center, with either a paced or self-paced schedule. It can also be used with individual students on a special basis.

Absenteeism - Because the instruction is individualized, a method of coping with absenteeism is built into the system.

Paraprofessionals - The system lends itself easily to the use of teacher aides for more routine operations such as test correction, record keeping, and even some tutoring.

Field Testing. Before its commercial publication, parts or all of the system were field tested in the technical mathematics course and other courses at MATC, in similar courses in other technical institutes in Wisconsin and neighboring states, and in secondary schools in the Milwaukee area. These field tests with over 4,000 students provided many constructive comments by teachers and students plus a wealth of test data, all of which were used to revise the textbooks and tests until a high level of learning was achieved by a high percentage of students.

Use of the System. The major use of the system of instruction at MATC is in a two-semester technical mathematics course which is a core course for students in the following technologies:

Industrial

Air Conditioning and Refrigeration Technology
Architectural Technology
Chemical Technology
Civil Technology: Highway Design
Civil Technology: Structural
Combustion Engines Technology
Electrical Technology: Electronics
Electrical Technology: Communications
Electrical Technology: Computer
Electrical Technology: Instrumentation
Fluid Power Technology
Mechanical Technology: Design
Mechanical Technology: Production
Metallurgical Technology
Photo-Instrumentation Technology
Welding Technology

Graphic Arts

*Printing and Publishing
**Photography
*Visual Communications

Service and Health

*Dental Laboratory Technology
*Environmental Health Technology
*Water and Waste Water Technology
Fire Technology
*Respiratory Therapy
*Medical Laboratory Technology
*Physical Therapy Assistant

*Take only one semester of technical mathematics.
**Take only one semester of an adapted technical mathematics.

Besides its use in the technical mathematics course at MATC, parts of the system are used in some apprentice, trade, and remedial programs. In cooperation with MATC, various secondary schools in the Milwaukee area are also using the system in a two-year technical mathematics sequence for students in grades 11 and 12.

Since the system of instruction is now commercially available, it is being used on a national basis. In technical institutes, its use is quite similar to that at MATC with the exception that some technical institutes use parts of the Series for a pre-technical mathematics course. At the two-year and four-year college level, some of the materials are used in remedial algebra courses. In secondary schools, the materials are generally used in a two-year technical mathematics sequence in grades 11 and 12 similar to that of the secondary schools in the Milwaukee area.

SYSTEM OF INSTRUCTION

A system of instruction is a highly-organized approach to education. It is a formal attempt to communicate some specific content to a specific group of students at some desired level of learning. By its very nature, a system of instruction is accountable. It is accountable for both the reasonableness of its learning objectives and the actual attainment of them by a specific group of students. In order to measure the latter, a system must include assessment instruments for its own evaluation.

In this section, we will describe and analyze the system of instruction as it is used in the technical mathematics course at MATC. After outlining how the system works, it will be discussed in terms of the following elements: (1) characteristics of the students, (2) content or learning objectives, (3) instructional materials, (4) assessment instruments, (5) role of the instructor, and (6) typical results. Though the technical mathematics course at MATC is taught in a learning center, this particular point will not be emphasized.

How the System Works. The procedure for using the system of instruction at MATC is briefly outlined below:

1. The entry diagnostic test in algebra is given to get an immediate assessment of the entry skills of the students. The scores on this test quickly identify the students with very high or very low entry skills.

2. Each chapter is covered in a number of daily assignments, usually three or four assignments. Each assignment is assessed by a special diagnostic test. Since these diagnostic tests are designed to take only 15 to 25 minutes, ample time is left for correction and tutoring within a normal class period. The diagnostic tests are not graded since they are simply a teaching tool.

3. After all assignments for a chapter are completed, one of the three equivalent forms of the chapter test is administered. Chapter tests are graded and grades are assigned on a percentage basis.

4. The comprehensive test for each textbook is included as a part of the final examination at the end of the semester.

Characteristics of the Students. A system of instruction cannot be developed in a vacuum. It is developed for a specific need of a specific type of student. In order to be successful, the system must take into account the academic history, entry skills, and learning capabilities of the students. These characteristics of the students entering the technical mathematics course at MATC are described in this section.

All entering technical students must have a high school diploma and must have completed one year of algebra and one year of geometry in high school. Other than these requirements, an "open door" policy is maintained by the school. The following points summarize the academic history of the students:

1. 65% to 70% rank in the bottom half of their high school classes.

2. 50% to 55% have not taken more than the two required years of college preparatory mathematics.

3. In the two years of required high school math, the percent receiving a "D", "U", or "not taking" increases from 35% to 40% in the first semester of algebra to 45% to 50% in the second semester of geometry.

4. Only 35% to 40% have taken a high school physics course or claim some ability to use a slide rule.

5. Except for English, their ACT scores compare favorably with the norms for junior colleges.

All entering students are given a pre-test in algebra at the beginning of the course. The mean scores on the 33-item algebra pre-test range from 30% to 35%. Table 1 gives the mean percent correct on each subsection of the algebra test for the 435 students in the Day Division in September, 1971.

TABLE 1

Means for Subsections of Pre-Test in Algebra
435 MATC Technical Mathematics Students (September, 1971)

		Correct	Incorrect	Not Attempted
Signed Numbers	(6 items)	51%	47%	2%
Algebraic Fractions	(7 items)	39%	50%	11%
Simple Equations	(6 items)	52%	38%	10%
Fractional Equations	(6 items)	23%	46%	36%
Formula Rearrangement	(8 items)	20%	39%	41%

Though it has not been administered during the last few years, a pre-test in arithmetic was also given to entering students in the earlier years of the project. Scores on the 55-item arithmetic pre-test ranged from 65% to 70%.

The great majority of the students we are describing are average or below-average learners. Individual differences are too great to permit a precise definition of learning characteristics which fit each average and below-average student. However, there are many characteristics which are evident in a significant number of students of this type. Though undoubtedly incomplete, the following list includes some of the more striking ones:

1. He learns rather slowly and needs a fair amount of practice for mastery.

2. He is easily confused because he does not automatically make all of the discriminations which are necessary for success in learning.

3. He is frequently unable to understand definitions, principles, or axioms which are communicated in abstract verbal or symbolic language.

4. His learning is quite specific. That is, he does not frequently transfer the principles and concepts he learns to stimuli which are dissimilar to those specifically used in teaching them.

5. He is frequently unable or unwilling to organize what he is doing. This lack of organization is reflected both in a lack of a plan of attack or strategy and in the carelessness of his work.

6. He does not always encode what he is trying to learn into verbal language, and when he does so, the encoding is frequently too imprecise to accurately control correct overt behavior.

7. His retention rate, as measured by pure recall, is not high.

The following general conclusions can be drawn about the academic history, learning capabilities, and entry skills of the students:

1. Though heterogeneous in terms of their high school achievement, the majority have not had a history of academic success.

2. Though their ACT scores are generally comparable to other entering junior college students, their low grades in high school suggest that they suffer from a lack of motivation, or lack of work habits, or both.

3. Though their average score on the arithmetic pre-test is satisfactory, many still have marked deficiencies in arithmetic.

4. Their average score on the algebra pre-test clearly demonstrates that most have marked deficiencies in algebra.

5. Their learning characteristics suggest that they need a highly-detailed, highly-controlled type of instruction.

The conclusions above, especially those concerning entry skills and learning characteristics, were carefully considered in decisions about content and method of instruction.

Content. The topics included in the course were determined by surveys of the science and technology teachers at MATC. However, the information obtained in these surveys was tempered by the judgment of staff members who took into account the entry skills and learning capabilities of the students. The chosen content is contained in the four textbooks of the MATC Mathematics Series:

BASIC ALGEBRA
CALCULATION AND SLIDE RULE
BASIC TRIGONOMETRY
ADVANCED ALGEBRA

The chapters in these four textbooks are listed in Table 2 on page 10. Some general features of the content are listed below:

1. Other than basic arithmetic operations with whole numbers and decimals, no other topics are assumed. Therefore, many topics which otherwise would have required extensive remedial work for a majority of the students are included as an integral part of the instruction.

2. The principles and concepts of "modern math" are used in order to give an understanding of mathematical concepts and procedures rather than to give an understanding of mathematical structure and proof.

3. Many topics included in similar courses are excluded. They are excluded either because they are not used in basic science or technology or because they are needed only as a preparation for a formal calculus course. Some excluded topics are: higher-degree equations, extensive operations with polynomials, a formal treatment of the conic sections, and complicated trigonometric identities.

4. Though the content includes many geometric and verbal problems, verbal-problem solving is not overdone. Contrived problems are avoided. Problems which require a knowledge of scientific or technical principles not known by a majority of the students are also avoided.

Programmed Textbooks and Learning Principles. The course content is communicated by means of programmed textbooks. There are four basic reasons why programmed materials are used:

1. Since class time is available for diagnosis and tutoring, daily personal attention can be provided for each student.

2. Programmed materials put the emphasis on student activity instead of teacher activity.

3. Programmed materials are a better method of communicating with average and below-average students since more details can be included in the instruction.

(Text continued on page 11.)

TABLE 2

MATC Mathematics Series

CHAPTER TITLES AND CHAPTER TEST RESULTS (1971-72)

BASIC ALGEBRA	Mean	Median
Chapter 1 - Signed Whole Numbers	97%	98%
Chapter 2 - Non-Fractional Equations	96%	97%
Chapter 3 - More Non-Fractional Equations	95%	100%
Chapter 4 - Multiplication and Division of Fractions	94%	96%
Chapter 5 - Addition and Subtraction of Fractions	89%	93%
Chapter 6 - Fractional Equations	93%	96%
Chapter 7 - Introduction to Graphing	96%	98%
Chapter 8 - Literal Fractions	90%	95%
Chapter 9 - Formula Rearrangement	94%	96%
Chapter 10 - Systems of Equations and Formula Derivation	86%	90%
CALCULATION AND SLIDE RULE		
Chapter 1 - Number System and Number Sense	95%	96%
Chapter 2 - Rounding and Rough Estimation	95%	98%
Chapter 3 - Introduction to Slide Rule	88%	92%
Chapter 4 - Powers of Ten	96%	98%
Chapter 5 - Slide Rule Multiplication and Division	82%	85%
Chapter 6 - Slide Rule Powers and Roots	88%	91%
Chapter 7 - Ratio, Proportion, Percent	80%	84%
Chapter 8 - Introduction to Logarithms	88%	92%
*Chapter 9 - Measurement Concepts	--	--
Chapter 10 - Geometric Formula Evaluation	85%	86%
BASIC TRIGONOMETRY		
Chapter 1 - Right Triangles and Trigonometric Ratios	95%	97%
Chapter 2 - Vectors	87%	88%
Chapter 3 - Trigonometric Ratios of Standard-Position Angles	92%	95%
Chapter 4 - Oblique Triangles	89%	89%
Chapter 5 - Applied Geometric Problems	72%	75%
Chapter 6 - Identities and Interpolation	89%	91%
Chapter 7 - Sine Wave Analysis	93%	95%
Chapter 8 - Complex Numbers	92%	93%
ADVANCED ALGEBRA		
Chapter 1 - Squares and Square Root Radicals	92%	96%
Chapter 2 - Equations and Formulas Containing Squares and Square Root Radicals	88%	92%
Chapter 3 - Quadratic Equations	82%	87%
*Chapter 4 - Exponents and Radicals	--	--
Chapter 5 - Linear Graphs and Slope	93%	95%
Chapter 6 - Common and Natural Logarithms	86%	89%
*Chapter 7 - Logarithms and Exponentials: Laws and Formulas	--	--

*Not taken during the 1971-72 school year because of time limitations.

4. Programmed materials are a useful method for coping with absenteeism.

The programmed materials have been revised several times during the history of the project. In the course of these revisions, the style of the materials has tended to stabilize. The major general characteristics of the materials are listed below:

1. All of the programming is linear. Though not denying the need for branching, this need is filled by the teacher's tutoring.

2. All of the instruction is straightforward exposition. There are no discovery exercises.

3. Each chapter is broken down into sub-units which are preceded by a verbal orientation and usually followed by a self-test.

4. Summary frames are introduced at appropriate places.

5. Detailed strategies and steps for all types of problems are shown.

Various principles of learning psychology are incorporated in the programmed materials. These principles are used in order to cope with the student's learning characteristics. A list of the more significant ones is given below:

1. The materials include a fair amount of practice in each new topic. This practice hopefully produces some overlearning which is an aid to retention.

2. Discrimination exercises are used to contrast operations which are frequently confused, orders of operations, technical terms, and so on.

3. Abstract verbal or symbolic definitions are avoided.

4. A wide range of transfer is not assumed. For the most part, all learning objectives are explicitly taught.

5. Formal strategies for solving equations, estimating answers, and problem solving are included. Short cuts are avoided, and ordinarily multiple methods of solving the same problem are deemphasized.

6. An effort is made to make the students verbally describe operations and strategies.

7. Review frames are inserted when needed in order to anticipate the forgetting which occurs.

Assessment Instruments. One of the most unique features of the system of instruction is the set of tests which it includes. These tests are an integral part of the instructional system and are contained in the following books available only to teachers:

TESTS FOR BASIC ALGEBRA
TESTS FOR CALCULATION AND SLIDE RULE
TESTS FOR BASIC TRIGONOMETRY
TESTS FOR ADVANCED ALGEBRA

Since the tests make possible a continual objective assessment, some control can be maintained over each student's learning process. This type of control has a marked effect on the amount of learning which occurs.

The general philosophy underlying all of the tests is one of diagnosis. The diagnosis is two-fold: (1) diagnosing the success of the system, and (2) diagnosing the success of individual students. Diagnosis of the success of the system is used to improve the system. Diagnosis of the success of individual students is used as a basis for tutoring. Since the primary purpose of the testing is diagnostic, transfer items are generally avoided. That is, the items are designed to measure that which is actually taught.

There are some general features which apply to all of the tests:

1. Since they are used as a basis for tutoring, a constructed-response format is used so that the student's work can be examined.

2. They are designed for rapid correction.

3. Adequate space is provided for each item so that the use of "scratch paper" is avoided.

The specific purpose and special features of each of the four types of tests are briefly discussed below:

Entry Tests - Entry tests in both arithmetic and algebra are provided. Each is designed for administration in one 50-minute period. The results of these tests quickly characterize the general entry skills of a class of students and the specific entry skills of individual students.

Assignment Tests - Each chapter is covered in three, four, or five assignments. A one-page diagnostic test is provided for each assignment. These tests, which are given daily during class periods, serve as a check that each student has both completed the assignment and mastered the learning objectives in it. By trial and error, the length of the assignments and assignment tests is such that the administration and correction of the tests and the necessary tutoring can be accomplished for a large number of students in a 50-minute class period. Since these tests are simply a teaching tool, they are not graded.

Chapter Tests - Chapter tests require a full 50-minute period. Since they are graded, three equivalent forms of each test are provided. Other than the obvious precaution against cheating, the three equivalent forms provide flexibility for retesting, handling absentees, and so on. The chapter tests are also used as a diagnostic tool since students are required to correct all errors.

Comprehensive Tests - A comprehensive test is provided for each textbook. Each comprehensive test is designed for administration in one 50-minute period. Though these tests could be given immediately after the completion of each book, at MATC they are included as part of the final examination at the end of the semester. They are also used as multi-topic review tests later in the course, and as a vehicle for making decisions about advanced standing.

Since both test correction and grading have an effect on the students' level of aspiration, fairly stringent standards are maintained in each. In order to encourage the students to be careful and accurate, a criterion of "perfectly correct" or "incorrect" is used in test correction. And in order to encourage the students to strive for a mastery level, grades are assigned on a strict percentage basis with 75% required for "passing" in the first semester and 70% required for "passing" in the second semester.

Role of the Teacher. A teacher is essential to the success of the system of instruction. The programmed materials and tests are simply highly-organized tools which give the teacher an opportunity to deal with students on an individual basis. In this system, the teacher's role can be described best by the phrase "manager of the learning process." The major functions of this role are: (1) controlling the level of aspiration and motivation of each student, (2) controlling the learning process of each student, and (3) organizing the classroom operation so that these two types of control can be accomplished as efficiently as possible.

The major ways in which the teacher controls the level of aspiration and motivation of each student are listed below:

1. In the initial orientation of students, "mastery" is emphasized as a desired and attainable goal.

2. Positive reinforcement ("praising") is used freely when students perform at a "mastery" level.

3. Negative comments about the student's ability or speed in learning are avoided.

4. The daily assignment tests are used as a measure of each student's effort.

5. The programmed textbooks are examined on a regular basis to make sure that each student is doing the required work.

The major way in which the teacher controls each student's learning process is by means of tutoring in conjunction with the daily diagnostic testing. Some of the qualities of a good tutor in this system are listed below:

1. Before tutoring, he lets the student attempt to correct his own errors first.

2. He uses the terminology and strategies taught in the programmed materials.

3. He avoids lectures to the whole class and deals with students on an individual basis as much as possible.

4. He addresses himself directly to the student's difficulty.

5. He avoids over-tutoring which makes the student unnecessarily dependent on the tutoring process.

6. He tries to make the student verbalize what he is doing as much as possible.

Though self-pacing obviously has merit when the materials are used on a more individual basis, a paced schedule is used in the technical mathematics course at MATC. Self-pacing has various negative features when it is used with a class of students in a formal course. Some of these major negative features are listed below:

1. Many students accomplish less because they are not sufficiently self-motivated to perform without the outside pressure of a schedule.

2. The teacher's work is increased because some type of record-keeping is needed to keep track of the progress of each student. This type of record-keeping is very time consuming and, therefore, the teacher cannot serve as many students.

3. Teachers have more difficulty tutoring because they must discuss learning problems with students who are at different places in the instructional materials. Teachers report that doing so imposes a cognitive strain which is tiring. They also report that they are more effective when tutoring students on a common assignment.

4. Though a few fast learners finish the materials quickly, many students begin with a spurt and then settle into a pace which is similar to, but only slightly ahead of, the majority of the class. This small gain is not worth the extra burden placed on the teacher.

The system lends itself quite easily to the use of teacher aides. Teacher aides can help with the test-correction, record-keeping, and even some of the tutoring. At MATC, second-year technical students are used as

aides. They are selected from a group whose names were suggested by teachers at the end of the echnical athematics course in the preceding year. They are paid on an hourly basis.

Typical Results. The success of a system of instruction is ultimately based on the amount of learning which occurs. Below we have summarized some typical results obtained in the technical mathematics course at MATC.

1. Average scores on chapter tests generally range from 85% to 95%. (The mean and median scores obtained on the chapter tests during the 1971-72 school year are given in Table 2 on page 10.)

2. Average scores on final examinations are usually between 80% and 85%.

3. With grades assigned on a strict percentage basis (75% required for a "D" in the first semester and 70% in the second semester), the majority of students receive A's or B's.

4. The dropout rate in the course has been reduced by 50%.

5. The rate of absenteeism has decreased.

6. Student motivation has not been a problem.

7. Student attitudes have been very positive. In a survey at the end of the 1968-69 school year:

   91% stated that they learned more than in previous mathematics courses.

   91% stated that they liked the course more than previous mathematics courses.

   97% stated that they would prefer the same type of instruction in any subsequent mathematics course.

When used in other contexts with other types of students and less experienced teachers, the results obtained have been somewhat lower. The achievement level is affected by the age, entry skills, and motivation of the students, and by the effectiveness of the instructor.

TECHNICAL MATHEMATICS IN SECONDARY SCHOOLS

Throughout its seven-year history, the project has been plagued by the unsatisfactory entry skills of the students. Because of these low entry skills, a significant amount of remedial content has been included in the technical mathematics course. Though needed in order to reduce the dropout rate, the presence of this remedial content has prevented both a proper articulation with some of the technical courses and the coverage of several relevant topics which should reasonably be included in a complete technical mathematics sequence. Many technical institutes handle the remedial problem by means of a pre-technical mathematics course with its accompanying delay in the technical programs. But since the majority of the entering technical students at MATC would have to be assigned to such a course if an entry-skill requirement were established, that solution to the remedial problem would presently be too disruptive of the technical programs.

As a long-range alternative to a pre-technical mathematics course, MATC is currently trying to establish a curricular liaison in mathematics with the secondary schools in its area. The secondary schools are being encouraged to include a two-year technical mathematics sequence in their curriculum in grades 11 and 12 for students who have completed one year each of algebra and geometry and intend to enroll in a post-secondary technical (or related) program. If the MATC Mathematics Series is used in the sequence, it is recommended that BASIC ALGEBRA and CALCULATION AND SLIDE RULE be covered in grade 11 and BASIC TRIGONOMETRY and ADVANCED ALGEBRA be covered in grade 12. This proposed two-year sequence fits the growing consensus that the recruitment and training of technicians would benefit if technician training programs began in grade 11 and encompassed the four-year period from grade 11 through grade 14.

Though the attempt to develop a curricular liaison in technical mathematics in secondary schools began on an informal basis with experimental classes in several schools, this effort has recently been aided by means of grants from the National Science Foundation to conduct In-Service Institutes in Technical Mathematics for Secondary School Teachers. Two such institutes were conducted during the 1971-72 school year. The fact that they attracted a total of 64 participants representing 31 high schools indicates substantial interest among secondary school personnel. Furthermore, the fact that 18 secondary schools in the Milwaukee area have included a technical mathematics sequence in their curriculum for the 1972-73 school year indicates that secondary schools are open to change. Similar in-service institutes are being conducted during the 1972-73 school year both at MATC and at the neighboring Waukesha County Technical Institute.

The establishment of a technical mathematics sequence in the secondary schools in the Milwaukee area will have beneficial effects both for the secondary schools and for MATC. For the secondary schools, it will fill a void in their curriculum and thus enable them to better serve a broader cross section of their students. For MATC, it will provide a forum for recruiting and a vehicle for increasing the entry skills of the students in its technical (or related) programs. These increased entry skills

will then enable MATC to upgrade its own technical mathematics course so that both a full coverage of content will be possible and the content can be better articulated with the technical courses. The establishment of this technical mathematics sequence will also institutionalize a curricular liaison in mathematics between MATC and the secondary schools in its area so that policies concerning advanced standing or accelerated programs at MATC can be jointly formulated.

The establishment of a two-year technical mathematics sequence in secondary schools also has broader implications. It is a first step toward the establishment of a full four-year career mathematics sequence in secondary schools for students who do not intend to obtain a baccalaureate degree. Since projections developed by the U. S. Bureau of Statistics indicate that approximately 80 percent of all jobs in the future will require less than four years of college training, the percentage of secondary students who will not obtain a baccalaureate degree represents the vast majority. Secondary schools do not presently have a four-year, career-oriented mathematics track for such students. Obviously, a separate four-year career mathematics track of this type will be necessary if the concept of career education is to have any impact on the secondary school curriculum.

DISCUSSION AND FUTURE DIRECTIONS

The MATC Mathematics Project was initiated in order to improve the instruction in a two-semester technical mathematics course for a variety of technical programs. The following three goals have been achieved:

1. The content of the course has been made more relevant to the needs of technical training.

2. The dropout rate in the technical mathematics courses has been cut approximately in half.

3. The achievement level of the students has been significantly increased.

Therefore, the project has been generally successful in accomplishing its stated goals. Furthermore, the system of instruction which has been developed contains many positive features which fit the modern trends in education. Some of these major positive features are listed below:

1. It is more humane because the students receive personal attention and are successful.

2. The content is both relevant to the needs of the students and realistic because it takes into account their entry skills and learning characteristics.

3. The effectiveness of the instruction has been highly assessed.

4. Since the development of the system has been based on the philosophy of accountability, improvements have been made in the instructional materials and in the management of the system until a high achievement level is attained by a high percentage of students.

5. It has made possible a more effective and efficient use of teaching manpower, including some paraprofessionals.

Though the project has generally been successful, the decision to include a significant amount of remedial content because of the low entry skills of the majority of the students has had some negative features, especially for the more mathematically-oriented technologies. The major improvements needed are a better articulation with some of the technical courses and a coverage of additional content. To accomplish these goals, MATC has broadened its perspective on the problem and now includes changes in the secondary school mathematics curriculum as part of the ultimate solution. The proposed long-range solution includes a four-year career mathematics sequence in secondary schools together with the corresponding changes in the technical mathematics course at MATC which that secondary school sequence would allow. In order to accomplish this long-range solution, many additions to the present system of instruction are contemplated. Besides an arithmetic at the bottom and a calculus at the top, various expansions are needed within the present system itself. These expansions would include more geometry, more algebra, a more complete treatment of measurement and measurement systems, and an introduction to some basic statistical concepts. Obviously, the success of the present system of instruction has not precluded the necessity for many additional years of development and improvement.